

CHAPTER 7

STRUCTURAL

7-1. GENERAL. This engineering discipline provides guidance for design of buildings and various other structural systems. Information or requirements contained in this chapter address structural engineering for hardened and ordinary construction, construction materials, computer usage, loading, structural systems, and miscellaneous structural features. Those requirements peculiar to structures and the classification of construction to be employed will be as described in the applicable project criteria documents. In this chapter, structures will be referred to as either hardened or ordinary construction. Hardened structures are defined as structures that must resist the effects of nuclear or conventional weapons effects, and accidental explosions.

7-2. PURPOSE AND APPLICABILITY. The purpose of this chapter is to outline requirements, responsibilities, and objectives for structural design. Requirements outlined are generally more rigid than those for non-Government activities. Newly designed structural systems should be compatible with their environment and fulfill functional needs at a reasonable cost consistent with structural objectives. Information provided in this chapter is suitable for use with all structural designs for which USAEDH has design responsibility.

7-3. REFERENCE DOCUMENTS

- a. Technical documentation used as basic guidance for ordinary construction follows:
 - (1) TM 5-805-7, Welding Design, Procedures and Inspection
 - (2) TM 5-809 Series, Structural Design
 - (3) TM 5-818-1/AFM-88-3, Soils and Geology, Procedures for Foundation Design of Buildings and Other Structures (Except Hydraulic Structures)
 - (4) TM 5-818-7, Foundations in Expansive Soils
 - (5) TM 5-855-1, Fundamentals of Protective Design for Conventional Weapons
 - (6) CEGS 05055, Guide Specification for Welding, Structural
 - (7) ANSI A58.1, Building Code Requirements for Minimum Design Loads in Buildings and Other Structures
 - (8) American Concrete Institute (ACI) 315, Details and Detailing of Concrete Reinforcement
 - (9) ACI 318, Building Code Requirements for Reinforced Concrete
 - (10) ACI 530, Building Code Requirements for Masonry Structures
 - (11) Low-Rise Building Systems Manual (MBSM), Metal Building Manufacturer's Association (MBMA)

- (12) American Institute of Steel Construction (AISC), Manual of Steel Construction (Allowable Stress Design)
 - (13) AISC, Manual of Steel Construction (Load and Resistance Factor Design)
 - (14) ASCE 7, Minimum Design Loads for Buildings and Other Structures
 - (15) Prestressed Concrete Institute (PCI)
 - (16) Steel Joist Institute (SJI)
 - (17) National Forestry Products Association (NFPA), National Design Specification for Wood Construction
 - (18) Timber Construction Manual, American Institute of Timber Construction (AITC)
 - (19) ER 415-1-10, Contractor Submittal Procedure
 - (20) ETL 1110-3-439, Masonry Veneer/Steel Stud Walls
 - (21) Federal Acquisition Regulations
- b. Technical documentation used as guidance for hardened structures follows:
- (1) TM 5-858 Series. Designing Facilities to Resist Nuclear Weapons Effects
 - (2) TM 5-1300/NAVFAC-P-397/AFM-88-22, Structures to Resist the Effects of Accidental Explosion
 - (3) DOE/TIC 11268, Manual for Prediction of Blast and Fragmentation Loading on Structures

7-4. CONCEPT DESIGN SUBMITTAL REQUIREMENTS

- a. Concept design analysis will be developed in accordance with the instructions in chapter 1, General Requirements. The specific content will be essentially as outlined below:
- (1) A statement identifying the design as one of the following: (a) an original design, (b) a site adaptation of standard design drawings, (c) a site adaptation of a previous design, or (d) a rehabilitation of an existing structure.
 - (2) A list of design criteria references.
 - (3) A list of structural design loads and conditions.
 - (4) A list of structural materials and identification of the proposed use of each material in each building structure.
 - (5) Description of the structural system for original designs. The vertical and lateral load resisting systems should be clearly described. The reason for selecting a particular framing system should be stated. The selection should be based on a cost comparison of at least three competitive systems. The systems considered and cost comparison results should be stated.

Selection of a system which is not the most economical system must be justified. In the event that design, architectural or functional requirements or site conditions dictate the system selection, a statement to this effect should be included and fully justified.

(6) Description of miscellaneous design features. Where applicable to the immediate project, include a description of each of the following design features.

(a) The proposed treatment of any unusual structural features or unique solutions to structural problems.

(b) Measures taken to compensate for expansion/contraction and crack control in masonry walls.

(c) Identification of any major vibrating elements and measures taken to isolate them.

(7) Site adaptations of standard or other existing designs. A description of the entire structural system is not required. Instead describe the proposed design changes necessary for adapting the design to the immediate project's site conditions and, when so instructed, address the design changes necessary for conformance with current design criteria.

(8) Structural computations to determine preliminary sizing and spacing of structural components.

b. Concept Drawings

(1) For original designs, drawings should show the following:

(a) Foundation plan and typical sections.

(b) Lateral load resisting system (shear walls, bracing, frames, etc.).

(c) Roof framing plan with sizing of typical members.

(d) Floor framing plan(s), where applicable, with sizing of typical members.

(2) For site adaptations of existing designs, list the titles and drawing numbers of the standard or other existing drawings with the basic revisions proposed.

c. Outline Specifications. All specifications used for each project (guide and/or A-E prepared) will be listed.

7-5. FINAL DESIGN SUBMITTAL REQUIREMENTS. This submittal will incorporate all accepted comments generated from the previous submittals.

a. Final Drawings. Furnish complete drawings and details of all structural elements. The following requirements will be incorporated:

(1) Show all intended sections, elevations, and details.

(2) Provide a complete set of general notes indicating design loads and material strengths.

(3) Use grade beam, slab, lintel, column, and footing schedules where the size of building warrants.

(4) Per the structural steel requirements discussed later in this chapter, all critical structural steel connections will be completely detailed and shown on the contract drawings. Critical connections are those connections subjected to moment, axial and shear loads, or combinations thereof. Only simple connections (i.e., connections classified as shear connections and subjected to shear loads only) may be deferred to the construction contractor for detailing.

(5) All reinforced concrete sections should be detailed in accordance with the Manual of Standard Practice for Detailing Reinforced Concrete Structures by the American Concrete Institute (ACI 315).

(6) All roof and floor openings, with details, will be shown on the structural drawings.

(7) Prior to this submittal structural drawings will be coordinated with all other design disciplines.

b. Final Design Analysis

(1) Original design calculations will be furnished for all structural members and systems such as foundations, frames, floors, roofs, stairways, equipment supports, and ancillary structures. All computations will be given a complete numerical and theoretical check. Calculation sheets will carry the names or initials of the designer and the checker, and the dates of calculations and checking.

(2) Site Adaptation Design of Standard Drawings. It is not necessary to develop complete structural calculations for a site adaptation because the adapted design is presumed to be correct and preapproved for which it was designed. A comparative analysis for site adaptations is required instead of complete calculations. The comparative analysis will identify the previous design being copied, list the structural differences (such as changes in design wind pressure and allowable soil bearing pressure), and provide computations for adapting the design to the site conditions.

(3) Site Adaptation of Previous Design. The A-E will verify that the previous design is adequate for the changed site conditions and new design loadings. A new foundation design will be prepared. A new design analysis will be submitted containing all the pertinent information and calculations from the original design analysis plus all the new information and calculations required above.

(4) Rehabilitation of an Existing Structure. The A-E will review the design documentation of the existing structure in order to determine the structural capability and limitations of the structure. The structural engineer should determine that the changes represented by the rehabilitation contract will not endanger any part of the existing structure. If the structural engineer's review results in negative findings, he/she will design and detail the alterations necessary to make the completed structure safe. The design, if any, will be incorporated into the final design analysis.

c. Final Design Specifications. Final specifications will be prepared in accordance with the instructions contained in chapter 3, Project Specifications.

7-6. STRUCTURAL SYSTEMS. Structural designs should use material efficiently, provide maximum usable space, minimize the use of special equipment, and be constructed by conventional methods. Consideration must be given to future uses of the structure, possibilities of alterations, and alternate functions and maintenance costs during the required lifetime of the structure.

a. Material Selection. Material selection factors that will be considered are shown in table 7-1.

b. Modular Design. Modular design features should be coordinated with architectural requirements favoring repetition of units. Beam depths and spacing, column spacing, floor heights, locations of openings, and clearances are typical considerations.

c. Type of Framing. Per ETL 1110-3-439, steel studs will not be used in bearing wall construction for interior or exterior walls. A determination on wall-bearing versus framed-structure will be made before selecting the type of framing system. The following factors will be weighed:

FACTOR	COMMENT
Height of Structure	Wall bearing construction usually is limited to one- or two-story structures.
Wall Openings	Framed structures are desirable where building walls have many openings.
Shock	Wall bearing structures are desirable for shock (blast) loads if intersecting cross walls are provided and if walls, floors, and roofs are rigidly connected. If the above provisions cannot be met, framed structures are preferable.
Seismic Construction	Approved structural framing systems to resist seismic loads are outlined in "Seismic Design for Buildings," TM 5-809-10.

d. Material Selected. The framing and material selected for design will be as recommended by the A-E based on the above considerations and approval by USAEDH.

7-7. COORDINATION. Coordination cannot be overemphasized. Structural drawings will be coordinated with other design disciplines. Special attention should be given to:

a. Specifications. The structural sections of the specifications will be checked against the design drawings. Where project specifications are furnished, they must be revised to embody all guide specification requirements and latest revisions.

b. Bonding and Grounding. Facilities may require bonding and grounding of metal work to eliminate interference with radio or radar operations explosive hazards, or for lightning protection. The structural engineer will coordinate facility criteria with the design so that bonding and grounding of reinforcing bars, structural steel, and other metal work can be easily

accomplished and can be shown in detail on the drawings, and will be in agreement with the appropriate electrical section of the specifications. For certain operations, floors will be sparkproof or electrically conductive.

7-8. SUBMISSION OF DESIGN CALCULATIONS. Structural design calculations will be submitted with the plans and specifications. Final structural calculations will be required. Computations will be indexed and arranged in an orderly manner, with basis of design followed by calculations and appropriate sketches shown, so that elements of the structure can be easily identified. The loads acting on the element will be calculated and the required physical properties of the element determined and shown on the sketches. Formulas, tables, curves, etc., used in calculations will be referenced. When computers are used to perform design calculations, in addition to other information required elsewhere in this manual, the calculations will include:

a. Basis for Design. The design will describe methods, assumptions, theories, and technical formulas employed in design solutions.

b. Computer Applications. Copies of computer data, accompanied by diagrams that identify supports, joints, members, and according to the notations used in the data listings, will form integral parts of the design calculations in lieu of manual computations otherwise required. These listings will be augmented with intermediate results, where applicable, so that sufficient information is available to permit manual checks of final results.

c. Information. The name and description of the computer programs will be provided. Other information will be in sufficient detail so the method of solution and limitations may be identified. A-E's are encouraged to use well-documented, widely accepted, structural analysis programs that are continuously maintained and enhanced by an experienced computer service organization.

d. Confidential or Proprietary Information. The use of confidential or proprietary information should be avoided. If proprietary or confidential computer programs are used, it is the responsibility of the designer to provide suitable documentation to the Government. In order to verify the accuracy of the proprietary or confidential program, sample problems should be solved and the results compared with results from a widely accepted structural analysis program.

e. Data Submission. Output data from critical load cases and all input data will be submitted for review. Data will be double checked for accuracy, data cards will be verified, and input data files used for final computations will be retained for the life of the construction contract. Final submission will include a set of checked computations marked final. Designers will provide signature approval that the data are complete and accurate. The practice of sending additional sheets to be incorporated with previously submitted computations is not acceptable. Unless otherwise instructed, where rigid frame or trussed bents are used, final submission will include summary sketch sheets showing loads and resulting reactions. Loads will include live, dead, wind, seismic, snow, crane, and other forces to which the frame will be subjected.

7-9. BASIC DESIGN REFERENCES. The basic structural design reference for buildings is TM 5-809-2. This manual covers buildings using concrete, steel, wood, or aluminum, and includes criteria for metal building systems and metal roofing and siding. Masonry design criteria is covered in TM 5-809-3, and TM 5-809-6 covers structures other than buildings such as transportation, site, and mechanical system structures.

7-10. DESIGN LOADS

a. General. TM 5-809-1 provides design load criteria for all design loads except seismic loads, which are covered in TM 5-809-10. The design load criteria in TM 5-809-1 are based on the requirements in ASCE 7 which must be obtained and used in conjunction with TM 5-809-1. Basic wind speeds, ground snow loads, and frost depth data for various major cities and military installations inside and outside the U.S. are provided in TM 5-809-1. The wind speeds and ground snow loads tabulated in TM 5-809-1 will be used in lieu of the tabulated wind speeds and ground snow loads in ASCE 7. As explained below, an exception to the design load criteria stated above is allowed for certain types of metal building systems.

b. Blast Load. See paragraph 7-20, Hardened Structures.

c. Exceptions. Following are exceptions to the design load stated above:

(1) **Standard Metal Building Systems.** For standard metal building systems, floor load combinations and procedures for developing the design loads will follow the criteria in the MBMA publication "Low Rise Building Systems Manual." Standard metal buildings have an eave height equal to or less than 6.0 m (20 feet), or have rigid spans less than or equal to 24.0 m (80 feet) (see TM 5-809-1). The following data will be used in developing design loads:

(a) Dead loads, floor live loads, basic wind speeds, and ground snow loads will be in accordance with TM 5-809-1. Roof live loads will be in accordance with MBMA requirements.

(b) Seismic zones are described in TM 5-809-10. Note that TM 5-809-10 has zones 2A and 2B instead of zone 2 as in MBMA. Zone 2A corresponds to zone 2 in MBMA. For buildings in zone 2B, use $Z = 0.50$ in the lateral force equation for seismic loads in MBMA.

(c) Importance factors for wind and snow loads will be obtained from ASCE 7. Importance factors for seismic loads will be obtained from TM 5-809-10. The building category will be obtained from this document for wind and snow loads and from TM 5-809-10/AFM 88-3, chapter 13 for seismic loads.

(2) **Special Purpose Metal Building Systems and Custom Metal Buildings.** For special purpose metal buildings systems and custom metal buildings, the load criteria in TM 5-809-1 and TM 5-809-10 will be used in place of the MBMA load criteria. Special purpose metal building systems are metal building systems designed by the manufacturer to meet loadings specified by the Government. These buildings have an eave height greater than 6.0 m (20 feet) or rigid frame spans greater than 24.0 m (80 feet), or are buildings considered to be special application types due to factors other than size, such as use, replacement value of contents, or location. Typical examples may be large gymnasiums, aircraft hangers, maintenance shops, or other large clear span industrial type buildings.

(3) Standard designs for buildings previously designed by other criteria for the same wind, snow, or seismic zone need not be redesigned when appropriately site adapted.

7-11. COMBINED LOADS. Loads will be combined to produce the worst case IAW requirements in TM 5-809-1.

a. Continuous Beams. Live loads will be placed on alternate spans of continuous beams to obtain maximum and minimum moments in any given span. Live loads will be placed

on adjacent spans to obtain maximum shear at the common support with nearby spans loaded alternately.

b. Roof. Combined roof loads will include other live loads such as crane loads.

c. Connections Between Elements. Historically, when failures of horizontal load resisting structural systems occur, the connections between the elements of the structural systems have been either the cause of the failure or a major contributing factor in the vast majority of the failure events. The cost of providing the connections between elements needed to resist design wind loads is a very small percentage of the total cost of the structural systems and an even more insignificant percentage of the total building cost. For these reasons, the connections between the major structural elements of the lateral load resisting system (except reinforced concrete frame connections) will resist the load combinations per ASCE 7, except that $2.0W$ will be substituted for W in the basic load combinations. (For example, the load combination $D+W$ becomes $D+2W$ for designing the connections only.) However, the connection strength need not exceed the strength of the connected structural member. This criteria is intended for low-rise buildings where the unfactored wind loads are small and do not control the size of the connection. Reinforced concrete moment frame connections will meet the requirements in ACI 318. Seismic design will conform to TM 5-809-10.

7-12. FOUNDATION DESIGN. USAEDH will furnish the A-E all necessary guidance and information for design of slabs-on-grade, building foundations, retaining walls and associated earth work, and other structural systems associated with soils. Early during prenegotiations the A-E will be advised as to the specific time when preliminary soils design data will be made available. Included in this data will be types of foundations, depths, allowable soil bearing pressures, coefficients of subgrade reaction, and other pertinent soils parameters. As a general rule the A-E may expect the preliminary soils data about a month after design start depending on the nature of the project. On a continuing basis during the design phase, USAEDH will provide supplemental soils data to the A-E as required. When requested, the A-E will furnish preliminary plans and schedules of column loads with dead and other long-term loads identified. This information will be used for analyses by USAEDH as deemed appropriate.

a. Expansion Soil Areas. Design of buildings founded on expansive soil should be based on the criteria in TM 5-818-7 and the criteria listed below. Where it is possible to found the building on a stable stratum such as gravel, rock, or a sufficient thickness of compacted engineering fill, the criteria may be neglected.

(1) Foundation. The foundation design analysis will indicate the type, or types, of foundation which can be used and will also indicate other special requirements such as carton-formed voids under grade beams and structurally supported first floors over a 150 mm (6-inch) minimum void. The foundation design analysis will also indicate any potential tensile forces caused by expansive soil, which may require additional vertical reinforcement.

(2) Framing. Due to the likelihood of differential movement, a primary consideration in framing selection is flexibility. Listed below are some acceptable framing systems:

(a) Steel framing systems (must be used on multi-story buildings).

(b) Load bearing walls (precast or masonry) supporting steel bar-joists. Masonry walls should be panelized by control joints.

(c) Monolithic cast-in-place, reinforced concrete frames can be used only if a rigid foundation, such as thick, solid mat slab is provided.

(3) Exterior Walls. The flexibility requirement, mentioned above for frames, also applies to walls. Precast concrete panels or insulated metal panels will provide adequate flexibility. Brittle finishes such as stucco or brick veneer should not be used unless panelized by control joints. Long, unbroken runs of masonry should be avoided where possible. Where not possible, control joints should be provided at 5.5 m (18 feet) on centers maximum.

(4) Interior Partitions. Use metal stud, gypsum board, dry-wall construction where possible. Where brittle finishes must be used, liberal use of control joints is required.

(5) Basements. Basements, especially partial basements, should be avoided if at all possible. But, if basements must be provided, the basement floors will be structurally supported over a 150 mm (6-inch) minimum void; perimeter wall drains will discharge to a sump; and exterior faces of basement walls will be water proofed. Earth pressure (k) values and special excavation/backfill requirements will be cited in the foundation design analysis.

(6) Bench Marks. When bench marks are required on building foundations (to monitor movement), use the detail in figure 7-1.

(7) Grading and Drainage. Care must be taken to ensure against ponding of water adjacent to the building foundation. Some considerations are:

(a) Grade sites to drain surface water well away from the building. This is particularly true for side-hill sites.

(b) Do not use plants or shrubs which require frequent watering adjacent to buildings.

(c) Areas subject to accidental spillage of water (air-conditioning cooling towers, etc.) should receive special attention to ensure discharge of spillage into storm drains or drainage away from the building.

(8) Utilities. Special consideration should be given to connections, suspension, and placement of underfloor utility lines to prevent damage due to soil heave. Testing should be done immediately before final acceptance of the building to detect leaks due to disturbance during construction. Roof drains should be carried down the outside of exterior walls where possible. Sewer, water, and drain lines in crawl spaces will be supported clear of the crawl space floor using trenches if necessary. The foundation design analysis will indicate whether special provisions must be made for underfloor utilities. In such cases, the Mechanical Section of the supervising district should be contacted for guidance.

b. Special Concrete Requirements. To alleviate deterioration of concrete due to sulfate action (Holloman AFB, White Sands Missile Range, etc.), the following requirements apply to all concrete used in foundation construction:

(1) Coarse and fine aggregates will be washed.

(2) Calcium chloride or admixtures containing chloride salts will not be used.

(3) All concrete will have air entrainment.

In addition all concrete less than 600 mm (24 inches) above finished grade, except for floor slabs within buildings and for concrete used for electrical systems (ducts, manholes, pull boxes, vaults, etc.), will:

- (a) contain Type V cement,
- (b) have an air content by volume of 5.5 percent plus or minus 1.5 percent,
- (c) contain no pozzolans,
- (d) contain not less than seven sacks of cement per cubic yard of concrete,
- (e) not exceed a slump of 75 mm (3 inches),
- (f) be moist cured for 10 days, and
- (g) receive a water proofing surface treatment consisting of two coats of linseed oil.

7-13. CONCRETE DESIGN. Concrete design will conform to TM 5-809-2 and ACI 318, Building Code Requirements for Reinforced Concrete. The selection of the strength of concrete and reinforcement will be based on economic considerations, taking into account the specific type and size of structure, architectural or special performance requirements, and construction cost factors for the building site.

a. Reinforcing Bar Placement. Particular attention will be stressed during design to prevent reinforcing from becoming congested at splices, intersections of beams with columns, and to insure proper clear distances between bars and concrete cover.

b. Expansion, Contraction, and Construction Joints. During the development of design, the A-E will consider the location and details of expansion joints in concrete structures. Horizontal and vertical spacing and details of all joints will be clearly indicated on the contract drawings.

c. Slabs-on-Grade. Concrete slabs-on-grade will be designed and detailed in conformance with TM 5-809-2 and TM 5-809-12 as appropriate. Crack control and construction and expansion joints will be as indicated in the TM's. Spacing and details of joints will be clearly indicated on the contract drawings.

(1) TM 5-809-2 provides criteria for design of slabs-on-grade NOT subject to significant wheel loadings, to heavy concentrated loads, or to static uniform loads in excess of 19 Pa (400 lb/SF).

(2) TM 5-809-12 provides criteria for design of slabs-on-grade subject to significant wheel loadings, to heavy concentrated loads, and to static uniform loads in excess of 19 Pa (400 lb/SF).

d. Reinforced Concrete Canopies. Where continuous reinforced concrete canopies are to be constructed on a building, open-type expansion joints will be provided in the canopies. Joints will generally be located at centerlines of columns, which are usually spaced approximately 6.0 m to 7.5 m (20 to 25 feet) on centers, and the joints will be no less than 40 mm (1-5/8 inches) wide. No water stop, joint filler, or caulking will be used in the finished joints. Care will be

exercised to ensure that reinforcing steel has normal concrete cover at joints and will not be exposed to weather.

7-14. MASONRY DESIGN. All masonry design must be in accordance with TM 5-809-3. All masonry design criteria and procedures are in the 1992 edition of TM 5-809-3. The 1992 edition of TM 5-809-10 contains only the specific seismic requirements, such as minimum reinforcement requirements for various seismic zones, minimum connections, and special detailing practices.

a. All masonry in seismic and nonseismic areas will be designed as reinforced masonry except that partitions in nonseismic areas may be designed as unreinforced masonry when satisfying the unreinforced masonry requirements of ACI 530. The 1992 edition of TM 5-809-3 does not contain design requirements for unreinforced masonry.

b. The previous moratorium placed by the Corps on the use of masonry veneer/steel stud wall systems for nonload bearing walls has been lifted. Masonry veneer/steel stud wall systems may be used for curtain wall masonry panels. These walls are designed to resist out-of-plane lateral loads due to wind and seismic forces. Masonry veneer/steel stud panel walls will not be used in bearing wall construction. Panel walls will not carry building dead or live loads nor provide lateral resistance to the building system.

c. Steel stud walls supporting masonry veneer will be designed for the maximum lateral wind and seismic loads with an allowable deflection of $L/600$. The masonry veneer will carry its own weight and wall anchors will be designed to allow differential movement parallel to the structure so the masonry veneer will not develop shear loads in the masonry veneer.

7-15. STRUCTURAL STEEL. Structural steel design will be in conformance with TM 5-809-2 and AISC Manual of Steel Construction (allowable stress design) or the AISC Load and Resistance Factor Design (LRFD) manual. The type of steel, the system framing, and the design method employed will produce the required structure at the least cost. Steel sections specified will be standard and readily available.

a. **Welded Structures.** The design of welded components, construction methods, and inspection procedures will be in accordance with TM 5-805-7. Welding details and specifications developed for welding joints will be developed in accordance with CEGS-05055.

b. **Weight of Section.** In order to expedite delivery, minimum weight section of structural steel shapes will be used wherever practicable.

c. **Connections.** High-strength steel bolts or welded connections will be used in either shop assembly or field erection of structural steel.

(1) The engineer-of-record is responsible for the design of all structural steel connections performed in-house. Architect-Engineers will ensure that all critical structural steel connections are completely detailed and shown on the drawings. Transferring this design responsibility to the construction contractor by wording on the drawings or through the specifications will not be permitted.

(2) Division and district offices preparing contract documents or having jurisdiction over A-E prepared designs will ensure that all critical structural steel connections are completely detailed and shown on the contract drawings. Critical connections are those connections subjected to moments, axial and shear loads, or combinations thereof.

(3) Only simple connections may be deferred to the construction contractor for design. Simple connections are connections classified as shear connections and subjected to shear loads only. Design and detailing of these connections should follow the AISC Steel Design Manual.

(4) Recognizing the increased engineering effort necessary to design all critical connections, whether designs are performed in-house or by an A-E, the design schedule should reflect the added engineering and drafting efforts. During the A-E negotiations, the requirement for complete design of the critical connections should be emphasized.

7-16. STEEL JOISTS. Steel joists will conform to Steel Joist Institute (SJI) Standard Specifications, Load Tables and Weight Tables for steel joists and joist girders, and TM 5-809-2. Only joists of standard manufacture and sizes and details will be used. Spacing of joists and location of bridging will be shown on framing drawings as well as live, wind (uplift), and other special loads. For final designs, joists and bridging design will be checked for interference with duct and roof vent installation and modified as required.

7-17. STRUCTURES OTHER THAN BUILDINGS. The design of structures other than buildings will be IAW TM 5-809-6, where applicable.

7-18. HARDENED STRUCTURES. In addition to the preceding requirements, hardened structures will be subject to the requirements of this section. Design will be IAW the regulations referenced in paragraph 7-3b.

a. Loads. AFWL-TR-74-102 and TM 5-858 (series) will be the basis for design loads from nuclear weapons effects. Structures designed to resist the effects of conventional explosions will conform to the requirements specified in TM 5-1300, HNMD 1110-1-2, and DOE/TIC 11268. TM 5-1300 provides loads primarily for design of reinforced concrete structures. HNMD 1110-1-2 provides loads for design of structures which partially or fully contain explosions. DOE/TIC 11268 provides additional data and design examples to supplement the other references.

b. Loads and Locations. For conventional explosions, the charge and its location used in the calculation will be consistent with the operation reflected in the final drawings. If a change in charge or location results in a significant variance, the design calculations will be changed and the drawings revised accordingly.

c. Stress and Ductility. The yield stress in structural members and the amount of acceptable deformation of members will be IAW the criteria documents above, unless specified otherwise.

d. Concrete Construction. Concrete structures that are to be hardened will be designed and detailed to provide continuity, ductility, and resistance to loading and rebound. Reinforcement will be lapped or welded adequately to assure continuity. Joints will be detailed to ensure ductile behavior of the entire element and, if practical, to develop the ultimate strength of the weakest connected element. Reinforced concrete barriers and containment structures capable of resisting accidental explosions will be designed and detailed IAW TM 5-1300 and HNMD 1110-1-2.

e. Structural Steel Construction. The use of steel construction is acceptable for major structures where economically feasible. Steel construction will be designed and detailed to

achieve continuity and full plastic strength. Bolted connections, when used, will be designed as bearing type, as opposed to friction type.

f. Other Material. The use of steel joists and masonry as structural systems for hardened structures will be allowed only when approved by USAEDH. For blast doors and windows, guidance will be provided by USAEDH.

g. Shock Isolation. Design of shock mountings will consider strength of connections to resist forces caused by accelerations and proper space for relative displacements of structure and equipment. Shock must be attenuated to a level that is acceptable to isolate equipment.

7-19. SEISMIC DESIGN FOR BUILDINGS AND OTHER STRUCTURES

a. General. TM 5-809-10 prescribes the criteria and furnishes guidance for the design of buildings and other structures, mechanical and electrical supports, and utility systems in areas subject to earthquakes. Preparation of seismic designs will be IAW the criteria and the TM design standards. Every building or structure and every portion thereof, if located in a seismic zone, will be designed to resist the stresses produced by the lateral seismic forces, as provided for in the TM. The provisions of the TM apply to buildings and structures as a unit and to all elements thereof. Design of anchorage supports for mechanical and electrical equipment are included, and should be provided in the structural design. Also, standard detail No. 000-90-01, Support Details for Seismic Protection of Mechanical and Electrical Equipment, will be provided by USAEDH for use in the design. Most structures will be designed by the static lateral force procedure discussed in TM 5-809-10. However, certain structures, as explained in TM 5-809-10, may require a dynamic analysis. The requirements in TM 5-809-10-1 will be used if dynamic analysis is required. TM 5-809-10-2 will be used to screen, prioritize, and evaluate the seismic resistance of existing structures. The seismic design of structural modifications will be in accordance with TM 5-809-10-1 if the existing structure contains nonconforming systems or materials (as defined in TM 5-809-10-2). If the existing structure contains conforming systems and materials, the seismic design criteria in either TM 5-809-10 or TM 5-809-10-1 will be used.

b. Facility Categories. Facilities are categorized in TM 5-809-10 as essential, hazardous, special occupancy, and standard occupancy to assist in determining the magnitude of the seismic forces the structure must withstand. USAEDH will furnish the A-E the facility "category."

c. Approved Structural Systems. TM 5-809-10 provides approved structural framing systems for use in seismic designed structures. The type of framing system has a direct impact on magnitude of seismic force. Final selection of systems and materials will be made with due consideration to cost of construction, architectural and functional requirements, resistance to rough usage, fire and other hazards, low maintenance and operating costs, and funds limitations.